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Segment Analysis of Otter Creek: The Location of Sources of Pollution

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SEGMENT ANALYSIS OF
Otter Creek

The Location of Sources of Pollution

Part of the Lake Ontario Watershed
Located in Orleans County

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Funded by the Orleans County Soil and Water Conservation District

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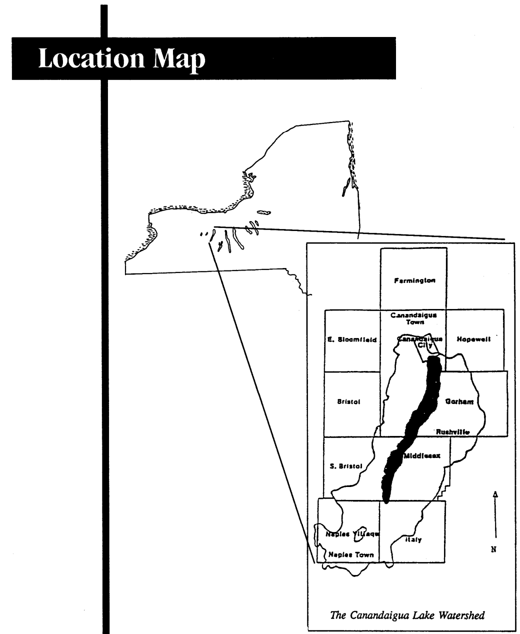
SUMMARY

The Orleans County Soil and Water Conservation District has monitored the waterways of Orleans County since 1997 in collaboration with the State University of New York at Brockport's Center for Applied Aquatic Science and Aquaculture (CAASA). SUNY Brockport has provided analytical services for water chemistry, consulting services on the direction of the monitoring program and interpretation of data. The Orleans County Soil and Water Conservation District along with the Orleans County Water Quality Coordinating Committee decided to continue the water pollution source identification in Otter Creek beginning in the spring of 2002. Otter Creek is located in the south portion of the Lake Ontario watershed, Orleans County, New York and flows into Oak Orchard Creek / Lake Alice in Waterport, New York. The goal of this project was to identify the sources of nutrients, soils and salts within the Otter Creek watershed. To accomplish this, point and non-point sources were identified through a process called stressed stream analysis or segment analysis. With this report, we provide evidence suggesting the location and the intensity of pollution sources in the Otter Creek watershed.



Canandaigua Lake Watershed in the Finger Lakes Region of New York State

We have identified two areas in the Otter Creek watershed that have consistently had high levels of nutrients, soils or sodium and one area that had high levels on one sampling date (Summary map contained in Figure 14). What follows is a synopsis of what pollutants are being lost and where the sources are located. Maps are included in the text to locate these sites.

1. **West County House Road to Eagle Harbor Road (Site 7 north to Site 6):**

   During the first event on 3 April 2002, the largest source of nutrients and soil to Otter Creek was detected between Sites 6 and 7 (Eagle Harbor Road near Phipps Road south to West County House Road). As Otter Creek flowed between these sites there was nearly a 100 percent increase of total phosphorus (124.3 to 228.8 µg P/L), total suspended solids (30.8 to 65.2 mg/L), total Kjeldahl nitrogen (590 to 1100 µg N/L) and soluble phosphorus

(49.3 to 79.9 µg P/L) concentrations. In general, water from the Erie Canal did not contribute large concentrations of any of the constituents monitored.

After further investigation in this area, the small tributary that crosses Eagle Harbor Road between West County House Road and Route 31 (Site 6B) was found to be contributing high concentrations of total phosphorus, nitrate, soluble reactive phosphorus and total Kjeldahl nitrogen to Otter Creek. The highest concentration of nitrate (9.43 mg N/L) and the second highest concentration of total phosphorus (294.5 µg P/L) and total Kjeldahl nitrogen (1360 µg N/L) were found at Site 6B. Site 6B represents the drainage of a large agricultural operation on the west side of Eagle Harbor Road.

2. Upstream of Site 8 on Route 31A:

Site 8 on Route 31A was identified as an area contributing high concentrations of nitrogen to Otter Creek. The source was narrowed down to Site 8B on Maple Street contained elevated levels of nitrate (1.94 mg N/L) and total Kjeldahl nitrogen (1,890 µg N/L). This area is typified by scrubland, woods and mixed agriculture.

3. Site 9 on Route 31A

Site 9, also on route 31A but west of Site 8, had the highest concentrations of total phosphorus, total suspended solids, and total Kjeldahl nitrogen during the 16 May 2003 event. High concentrations were not observed at this site during previous sampling dates. This area is bordered by large agricultural operations on the south side of Route 31A.

RECOMMENDATIONS

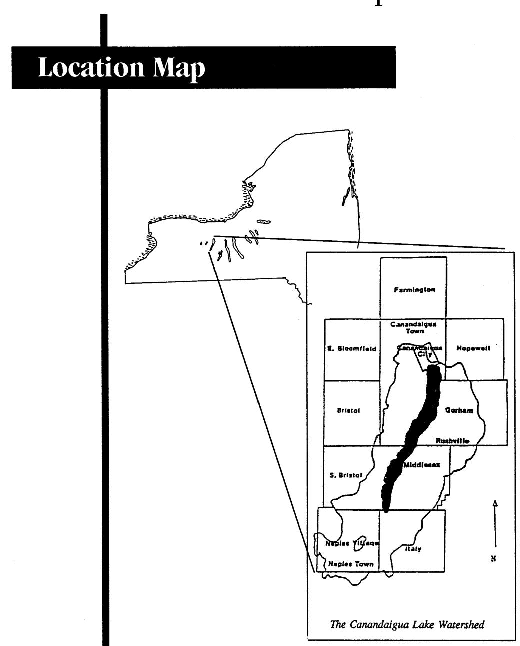
1. An additional hydrometeorological event or two should be sampled on Otter Creek. An expanded set of sampling sites should be monitored to pinpoint the source(s) of nutrients and soil that have already been identified as contributing high concentrations to Otter Creek.
2. Additional samples need to be taken upstream from Site 6B on Eagle Harbor road to better understand the sources of nutrients found at that site.
3. Similarly, Site 8B on Maple Street should be investigated further due to its elevated levels of nitrogen.
4. Site 9 on Route 31A should be sampled again as it showed high concentrations of total phosphorus, total suspended solids, and total Kjeldahl nitrogen during the 16

May 2003 event only. This source should be confirmed.

5. In general, after careful inspection of areas identified as sources of pollution and perhaps some further sampling, Best Management Practices should be introduced to remediate these sites. This would necessitate working with the Water Quality Coordinating Committee and various users to assist them in their stewardship of the land they own.

INTRODUCTION

The Orleans County Soil and Water Conservation District has monitored the waterways of Orleans County since 1997 in collaboration with the State University of New York at Brockport's Center for Applied Aquatic Science and Aquaculture (CAASA). Monitoring efforts have included the installation of a permanent gauging and sampling stations located on Johnson Creek, Sandy Creek and Oak Orchard Creek (1,2). The District and SUNY Brockport have also completed a Stressed Stream Analysis on Johnson Creek in 2001 (3). SUNY Brockport has provided analytical services for water chemistry, data interpretation, as well as consulting services on the direction of the monitoring program.



Canandaigua Lake Watershed in the Finger Lakes Region of New York State

Otter Creek is located in the south portion of the Lake Ontario watershed, Orleans County, New York (Fig. 1) and flows into Oak Orchard Creek / Lake Alice in Waterport, New York. The goal of this project was to identify the sources of nutrients, soils and salts within the Otter Creek watershed. To accomplish this, point and non-point sources were identified through a process called stressed stream analysis or segment analysis (4). With this report, we provide evidence suggesting the location and the intensity of pollution sources in the Otter Creek watershed.

The Approach:

Point and non-point sources of nutrients, soils and salts were identified through a process called stressed stream analysis or segment analysis (4). This approach identifies impacted sub-watersheds and their associated streams (3,5,6,7,8,9,10). Within a subwatershed, stressed stream analysis is an approach for determining how and where a stream and its ecological community are adversely affected by a pollution source or other disturbances. Stressed stream analysis is an integrative, comprehensive approach for determining the environmental health of a watershed and its constituent streams. It is a technique that identifies the sources, extent, effects and severity of pollution in a watershed. In its fullest use, it combines elements of the sciences of hydrology, limnology, ecology, organismal biology and genetics in an integrated approach to analyze cause and affect relationships in disturbed stream ecosystems.

Within a sub-watershed, the stream is used to monitor the "health" of the watershed. Because nutrients are easily transported by water, they can be traced to their source by systematic geographic monitoring of the stream. Stressed stream analysis is a technique that divides the impacted sub-watershed into small distinct geographical units – segment analysis. Samples are taken at the beginning and end of each unit of the stream to determine if a nutrient source occurs within that reach. At completion, the cause and extent of pollution have been identified. If needed, the severity of the pollution within the impacted sub-watershed and or the entire watershed can then be evaluated by spatial analysis of the quantity and quality of biological indicators, such as fish and invertebrates, and by biological examination of structural and functional changes in individual organisms and populations in affected communities. Once identified, sources of chemical pollutants may be corrected using "Best Management Practices" (BMP). In this report, stressed stream analysis is limited to a spatial analysis of chemical sources of Otter Creek.

DEFINITIONS

Total Phosphorus- A measure of all forms of the element phosphorus. Phosphorus is an element required for plant growth on land or in water. In lakes, phosphorus is often the limiting factor of phytoplankton growth and is the cause of eutrophication, or overproduction, of lakes. Phosphorus may enter a watershed in soluble or organic form from several sources including sewage, heavy-duty detergents, fertilizer and agricultural waste. Some forms of phosphorus are more available to, and cause more immediate activity in, plants.

Soluble Reactive Phosphorus- A measure of the most available and active form of phosphorus.

Nitrate + Nitrite- A measure of the soluble forms of nitrogen used readily by plants for growth. Sources of nitrates in the environment are many and include barnyard waste and fertilizer.

Total Kjeldahl Nitrogen- The Kjeldahl method is a convenient method of analysis for nitrogen but cannot be used for all types of nitrogen compounds. It is, however, a good measure of organic nitrogen, including ammonia. Manure, for example, contains a large amount of organic nitrogen.

Sodium- A measure of the mineral, most commonly found as sodium chloride (NaCl), dissolved in water. NaCl naturally occurs in deep layers of local bedrock. Mined, it is stored and spread as a de-icing agent on roads and other pavements.

Total Suspended Solids - A measure of the loss of soil and other materials suspended in the water from a watershed. Water-borne sediments act as an indicator, facilitator and agent of pollution. As an indicator, they add color to the water. As a facilitator, sediments often carry other pollutants, such as nutrients and toxic substances. As an agent, sediments smother organisms and clog pore spaces used by some species for spawning.

SAMPLING AND ANALYTICAL METHODS

Segment analysis was performed on four dates on Otter Creek (3 April 2002, 18 March 2003. 16 May 2003 and 29 August 2003). Sampling locations are shown on Figure 1. All samples were analyzed for nitrate, soluble reactive phosphorus, total phosphorus, total Kjeldahl nitrogen, sodium, and total suspended solids. Nichelle Billhardt, Judy Bennett and John Brennan of the Orleans County Soil and Water Conservation District completed the field sampling. During the initial stressed stream analysis on 3 April 2002, eleven stations were sampled under event conditions covering the major segments of the tributary (Fig. 1). Heavy rains had occurred the previous day with reports of 1 to 3 inches falling in Orleans County. The same stations were sampled on 18 March 2003 during another hydrometeorological event. Based on these analyses, stations were added to the segment analysis to further pinpoint sources of pollution identified during the first two sampling events. The areas that were further investigated were between Eagle Harbor Road near Phipps Road south to West County House Road (between Sites 6 and 7) and South of Route 31A just west of Gaines Basin Road (Site 8). On subsequent sampling dates, sampling was expanded in these sub-watersheds that showed particularly high values during the previous sampling efforts. Samples were also taken during baseline conditions on 29 August 2003. An additional grab sample was taken at the base of Fish Creek on each sampling date to evaluate the necessity of future work in that stream. All samples were generally taken within 180 minutes. Specific locations of all sampling sites are shown in Figures 1-13.

All sampling bottles were pre-coded so as to ensure exact identification of the particular sample. All sample bottles were routinely cleaned with phosphate free RBS between sampling dates. Containers were rinsed prior to sample collection with the water being collected. In general, all procedures followed EPA standard methods (11) or Standard Methods for the Analysis of Water and Wastewater (12). Sample water for dissolved nutrient analyses (SRP, nitrate + nitrite) was filtered immediately with 0.45-µm MCI Magna Nylon 66 membrane and either frozen or analyzed within 24 hours of collection.

Nitrate+Nitrite: Dissolved nitrate+nitrite nitrogen were performed by the automated (Technicon autoanalyser) cadmium reduction method (12).

Soluble Reactive Phosphorus: Sample water was filtered through a 0.45-µm membrane filter. The filtrate was analyzed for orthophosphate using the automated (Technicon) colorimetric ascorbic acid method (12). The formation of the phosphomolybdeum blue complex was read colorimetrically at 880nm.

Total Phosphorus: The persulfate digestion procedure was used prior to analysis by the automated (Technicon autoanalyser) colorimetric ascorbic acid method (12).

Total Kjeldahl Nitrogen: Analysis was performed using a modification of the Technicon Industrial Method 329-74W/B. The following modifications were made:

- In the sodium salicylate-sodium nitroprusside solution, sodium nitroprusside was increased to 0.4 gm/L.
- The reservoir of the autoanalyser was filled with 2M H_2SO_4 instead of distilled water.
- Other reagents were made fresh prior to analysis.

Sodium: Sodium analysis was performed by Atomic Absorption Spectrophotometry (12).

Total Suspended Solids: APHA (1995) Method 2540D was employed for this analysis.

QUALITY CONTROL

The Water Chemistry Laboratory at SUNY Brockport is certified through the New York State Department of Health's Environmental Laboratory Approval Program (ELAP - # 11439). This program includes bi-annual proficiency audits, annual inspections and good laboratory practices documentation of all samples, reagents and equipment (Table 1).

RESULTS

Chronological Account of Stressed Stream Analysis:

3 April 2002 (Figures 2-4, Table 2)

The initial sampling event occurred during rain conditions, where one to three inches of rain were reported across Orleans County on the previous day. Sampling during this initial analysis took place at major intersections of Otter Creek. This was done to initiate the program and to determine the variability of nutrient concentrations along the major sections of Otter Creek. Ten stations were sampled in the Otter Creek watershed and results are presented in Table 2 and Figures 2-4. Additional samples were taken where the Erie Canal spills into Otter Creek and at the base of Fish Creek.

The largest source of nutrients and soil to Otter Creek was detected between Sites 6 and 7 (Eagle Harbor Road near Phipps Road south to West County House Road). As Otter Creek flowed between these sites there was nearly a 100 percent increase of total phosphorus (124.3 to 228.8 µg P/L), total suspended solids (30.8 to 65.2 mg/L), total Kjeldahl nitrogen (590 to 1100 µg N/L) and soluble phosphorus (49.3 to 79.9 µg P/L) concentrations. In general, water from the Erie Canal did not contribute large concentrations of any of the constituents monitored.

18 March 2003 (Figure 5-7, Table 2)

During a snowmelt event on 18 March 2003, the same 10 stations on Otter Creek were sampled again. In general, nitrate was higher at every station during this second analysis, with the highest concentration (3.13 mg N/L) at Site 5 on Eagle Harbor – Knowlesville Road. The fact that the majority of water running off the watershed during this event was from snowmelt resulted in total suspended solid values that were generally low. A large increase in total phosphorus (38%) occurred from Site 7 (Eagle Harbor Road near Phipps Road) to Site 6 (West County House Road). Similarly, soluble reactive phosphorus increased forty percent while total Kjeldahl nitrogen increased 20% from 980 to 1180 µg N/L between the same two sites. The highest concentration of total Kjeldahl nitrogen (1320 µg N/L) was found at Site 8 on Route 31A.

The number of stations will be expanded in an attempt to isolate the source of the high nutrient concentrations between Sites 7 and 6 as well as upstream from Site 8.

16 May 2003 (Figures 8-10, 14, Table 2)

Fifteen sites on Otter Creek were sampled during a precipitation event on 16 May 2003. Two additional sites were added between Sites 6 and 7 (Eagle Harbor Road near Phipps Road south to West County House Road) to attempt to further pinpoint the source(s) of nutrients observed during the previous sampling periods. Similarly, two additional sites were added upstream from Site 8 on Route 31A.

West County House Road to Eagle Harbor Road (Site 7 north to Site 6):

The additional samples taken in this area of Otter Creek show that the small tributary that crosses Eagle Harbor Road between West County House Road and Route 31 (Site 6B) is contributing high concentrations of total phosphorus, nitrate, soluble reactive phosphorus and total Kjeldahl nitrogen. The highest concentration of nitrate (9.43 mg N/L) and soluble reactive phosphorus (82.4 µg P/L) and the second highest concentrations of total phosphorus (294.5 µg P/L) and total Kjeldahl nitrogen (1360 µg N/L) were found at Site 6B. Site 6B represents the drainage of a large agricultural operation on the west side of Eagle Harbor Road.

Site 6B on Eagle Harbor Road

Upstream of Site 8 on Route 31A:

The area upstream of Site 8 on Route 31A was also investigated further during this event. Site 8B on Maple Street contained elevated levels of nitrate (1.94 mg N/L) and total Kjeldahl nitrogen (1,890 µg N/L). This area is typified by scrubland, woods and mixed agriculture.

Site 8 on Route 31A

Site 9, also on route 31A but west of Site 8, had the highest concentrations of total phosphorus, total suspended solids, and total Kjeldahl nitrogen during this event. High concentrations were not observed at this site during previous sampling dates. This area is bordered by large agricultural operations on the south side of Route 31A.

29 August 2003 (Figures 11-13, Table 2)

Baseline conditions were sampled on 29 August 2003 by SWCD personnel. Relatively high concentrations of phosphorus were observed in the upper part of the Otter Creek watershed (Sites 4, 5 and 6). Although the concentrations of TP and SRP were relatively high, the flow at these sites was very low minimizing the impact of phosphorus on downstream locations. As expected, total suspended solids were low throughout the watershed on 29 August 2003. Elevated levels of total Kjeldahl nitrogen were found at Sites 4 and 6, the sites below the small reservoirs in the watershed. The highest sodium concentration (105.24 mg/L) was recorded at Site 5, with no obvious cause. Nitrate was relatively constant throughout the entire watershed during this baseline condition.

DISCUSSION

The quality and quantity of runoff from a watershed into a stream are ultimately influenced by people. The amount of runoff is determined by the amount of excess precipitation, that which neither sinks into the ground nor is stored at the surface. Precipitation excess is determined primarily by climate, vegetation, infiltration capacity, surface storage and land use by people. Impervious landscapes (e.g., parking lots), removal of wetlands and vegetation in general, storm sewers, blockage of streams by debris, etc., all contribute to rapid rises in stream level and potential flooding. Similarly, land usage contributes to the quality of the water in the stream and ultimately Lake Ontario. For example, deicing salt spread on roads is easily dissolved and accumulates in streams raising the concentration of sodium in water. Another example is the spreading of manure on the land. If done properly, this can be a reasonable practice enriching the soil. If not, the result may be elevated levels of fecal coliform bacteria and increased levels of phosphorus, organic nitrogen and nitrates that cause health concerns or cause eutrophication of down stream systems. Land use practices initiated by people can and do affect stream water quality and stream discharge. If we can identify the sources of pollution, remedial action plans and best management plans can be initiated that mitigate downstream and lake effects.

Best Management Practices:

Identified point and non-point sources of nutrients and solids can be remediated using Best Management Practices (BMP). Whether or not management practices include a reduction of cropland or fertilization, control of water movement can be a means of significantly reducing non-point source pollution. Since water must come in contact with the nutrient source and then be transported to the surface (or subsurface) water body, the nutrients in water bodies are functions of soil fertility and quantities of transporting water. Management practices, which reduce surface runoff, have been shown to dramatically decrease the magnitudes of sediment and chemical losses from land areas (13).

Agriculture: Haith (13) and the NYSDEC (14, 15) recommend use of buffer strips of forest or grass between the pollutant source and a stream to intercept the runoff, resulting in removal by deposition or filtering by the vegetative cover. Other cropland management practices include diversions, terraces contour cropping, strip cropping, waterways, minimum and no tillage. Livestock operation controls include barnyard runoff management, manure storage facilities and livestock exclusion from woodlands. They may also include structural devices such as grassed waterways, sediment retention basins, erosion control weirs and animal waste holding tanks. BMP's are designed to reduce sediment and nutrient transport to streams and lakes. They may benefit the farmer in the long term by decreasing fuel and fertilizer costs and by improving soil productivity. Furthermore, the advent of Concentrated Animal and Feed Operations (CAFO) permits, regulatory control of farms with large numbers of animals may be inevitable.

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Table 1. Results of the semi-annual New York State Environmental Laboratory Assurance Program (ELAP Lab # 11439, SUNY Brockport) Non-Potable Water Chemistry Proficiency Test, July 1999. Score Definition: 4 (Highest) = Satisfactory, 3 = Marginal, 2 = Poor, 1 = Unsatisfactory.

WADSWORTH CENTER

NEW YORK STATE DEPARTMENT OF HEALTH
ENVIRONMENTAL LABORATORY APPROVAL PROGRAM

Proficiency Test Report

Lab 11439 SUNY BROCKPORT EPA Lab ID NY01449 Page 1 of 1
WATER LAB LENNON HALL
BROCKPORT, NY 14420
USA

Shipment 255 Non Potable Water Chemistry
Shipment Date: 22-July-2002

Analyte	Sample ID	Result	Mean/Target	Satisfactory Limits	Method	Score
Approval Category : **Non Potable Water**						
Sample: **Residue**						
Solids, Total Suspended 280 passed out of 302 reported results.	5502	54.0	51.4	45.5 – 57.2	SM18 2540D	Satisfactory
Sample: **Organic Nutrients**						
Kjeldahl Nitrogen, Total 120 passed out of 122 reported results.	5504	9.95	9.78	7.96 – 11.6	EPA 351.3	Satisfactory
Phosphorus, Total 132 passed out of 145 reported results.	5504	8.87	8.12	6.98 – 9.26	SM18 4500-PB,E	Satisfactory
Sample: **Inorganic Nutrients**						
Nitrate (as N) 113 passed out of 120 reported results.	5507	6.22	6.33	5.47 – 7.19	SM18 4500-NO3 F	Satisfactory
Orthophosphate (as P) 94 passed out of 106 reported results.	5507	0.735	0.717	0.636 – 0.799	SM18 4500-P F	Satisfactory
Sample: **Metals I and II**						
Sodium, Total 102 passed out of 120 reported results.	5511	69.0	69.6	65.1 – 74.1	ASTM D-1688-95 C	Satisfactory

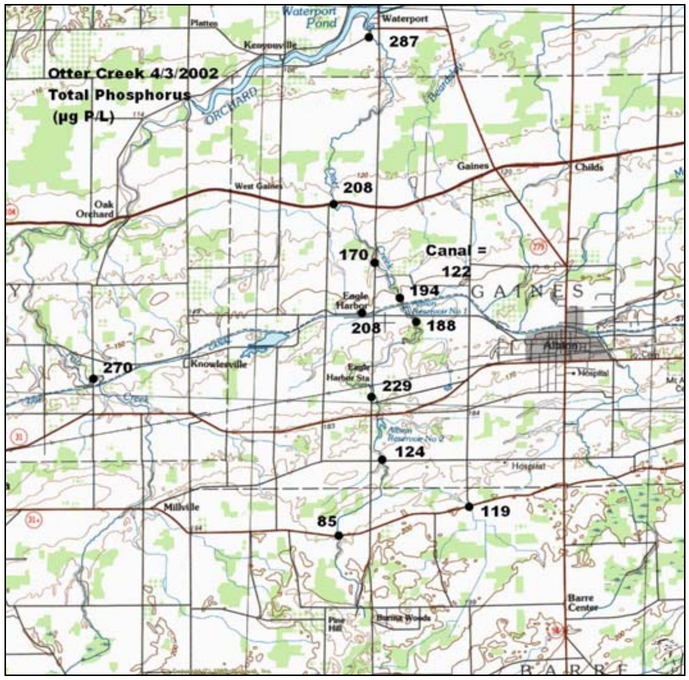
Table 2. Water chemistry data for Otter Creek. TP = total phosphorus, SRP = soluble reactive phosphorus, TKN = total Kjeldahl nitrogen, TSS = total suspended solids.

Sample	Date Collected	TP (µg P/L)	Nitrate (mg N/L)	TSS (mg/L)	TKN (µg N/L)	Sodium (mg/L)	SRP (µg P/L)
Orleans Base Otter Creek SSA	4/3/2002	286.8	1.20	104.5	1170	20.50	32.7
Orleans 1	4/3/2002	208.2	1.56	79.5	1150	19.10	37.2
Orleans 2	4/3/2002	170.4	1.35	58.3	1110	24.40	37.9
Orleans 3	4/3/2002	193.7	1.33	63.0	1020	18.60	43.4
Orleans 4	4/3/2002	187.8	1.45	66.8	1150	21.00	63.6
Orleans 5	4/3/2002	208.2	1.83	61.0	1100	7.40	51.8
Orleans 6	4/3/2002	228.8	1.37	65.2	1100	15.20	79.9
Orleans 7	4/3/2002	124.3	1.09	30.8	590	16.10	49.3
Orleans 8	4/3/2002	119.1	0.80	30.6	810	10.70	38.9
Orleans 9	4/3/2002	84.7	0.94	12.8	510	8.40	44.5
Orleans 10 Fish Creek Base	4/3/2002	269.6	0.91	86.3	1060	7.00	36.5
Orleans Canal	4/3/2002	122.0	0.41	38.6	710	25.80	41.4
Otter Creek Base	3/18/2003	201.3	2.92	35.0	1160	17.55	114.0
Otter Creek 1	3/18/2003	230.2	2.70	48.5	1020	18.20	146.7
Otter Creek 2	3/18/2003	240.2	2.98	31.5	1260	19.37	145.1
Otter Creek 3	3/18/2003	223.6	2.88	12.4	1260	19.48	140.2
Otter Creek 4	3/18/2003	219.1	2.95	11.0	1380	16.06	150.0
Otter Creek 5	3/18/2003	86.8	3.13	13.4	1070	5.93	44.1
Otter Creek 6	3/18/2003	236.9	3.00	11.0	1180	13.52	159.9
Otter Creek 7	3/18/2003	171.3	2.66	7.7	980	14.90	114.0
Otter Creek 8	3/18/2003	172.4	1.93	28.4	1320	11.29	99.2
Otter Creek 9	3/18/2003	173.5	2.44	10.9	750	4.42	112.3
Fish Creek 10	3/18/2003	172.4	3.78	35.0	880	4.60	90.2

Table 2 (cont.). Water chemistry data for Otter Creek. TP = total phosphorus, SRP = soluble reactive phosphorus, TKN = total Kjeldahl nitrogen, TSS = total suspended solids.

Sample	Date Collected	TP (µg P/L)	Nitrate (mg N/L)	TSS (mg/L)	TKN (µg N/L)	Sodium (mg/L)	SRP (µg P/L)
Fish Creek Base	5/16/2003	148.0	4.24	11.7	980	23.72	32.1
Otter Creek Base	5/16/2003	89.6	1.50	8.8	790	29.46	23.0
Otter Creek 1	5/16/2003	75.1	1.93	19.3	690	30.60	22.6
Otter Creek 2	5/16/2003	71.8	1.78	13.8	630	30.13	21.6
Otter Creek 3	5/16/2003	69.1	1.78	12.5	610	30.49	25.4
Otter Creek 3a	5/16/2003	77.2	0.57	17.1	550	36.21	22.6
Otter Creek 4	5/16/2003	69.1	2.13	11.2	920	27.87	24.0
Otter Creek 5	5/16/2003	127.9	3.11	19.6	1170	18.61	33.8
Otter Creek 6	5/16/2003	91.8	1.92	14.5	830	27.75	26.7
Otter Creek 6a	5/16/2003	105.8	0.74	19.6	900	21.19	32.1
Otter Creek 6b	5/16/2003	294.5	9.43	35.0	1360	21.71	82.4
Otter Creek 7	5/16/2003	127.5	1.72	29.6	820	29.13	37.6
Otter Creek 8	5/16/2003	109.0	1.67	13.6	1430	24.29	48.7
Otter Creek 8a	5/16/2003	121.0	0.39	15.9	1230	7.66	54.5
Otter Creek 8b	5/16/2003	112.3	1.94	<0.2	1890	13.46	57.5
Otter Creek 9	5/16/2003	372.7	1.48	45.6	4050	15.36	11.1
Otter Creek Base	8/29/2003	63.1	0.62	5.0	440	19.92	46.6
Otter Creek 1	8/29/2003	61.0	0.83	7.8	410	18.36	37.5
Otter Creek 2	8/29/2003	59.9	0.89	6.7	440	17.15	22.3
Otter Creek 3	8/29/2003	65.6	0.83	13.2	500	17.26	46.0
Otter Creek 3a	8/29/2003	63.9	0.76	10.3	510	16.92	20.2
Otter Creek 4	8/29/2003	274.9	0.11	0.8	1130	51.18	113.6
Otter Creek 5	8/29/2003	134.4	0.32	2.1	970	105.24	58.9
Otter Creek 6	8/29/2003	163.6	0.38	6.8	1020	68.85	81.9
Fish Creek Base	8/29/2003	53.5	0.67	0.5	640	20.85	49.4

Figure 1. The Otter Creek watershed, Orleans County, New York with stressed stream sampling locations.



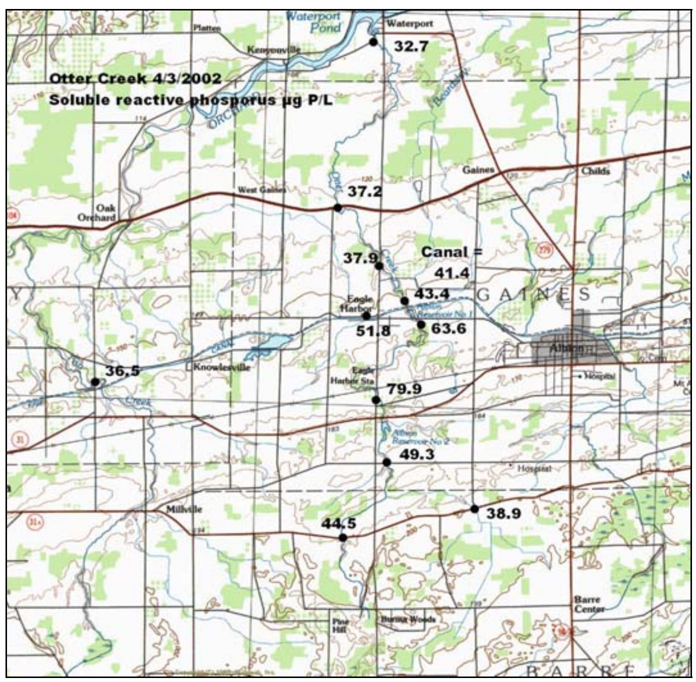
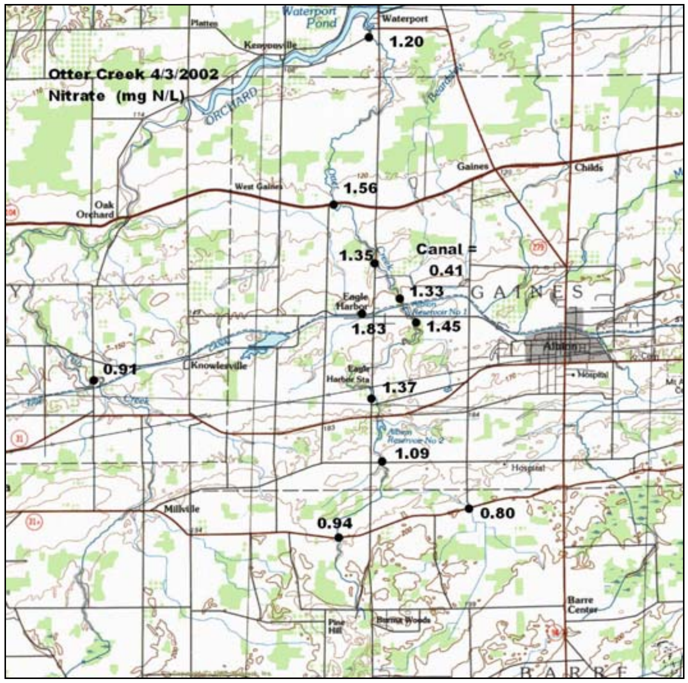


Figure 2. Total phosphorus and soluble reactive phosphorus for Otter Creek and the base of Fish Creek on 3 April 2002.



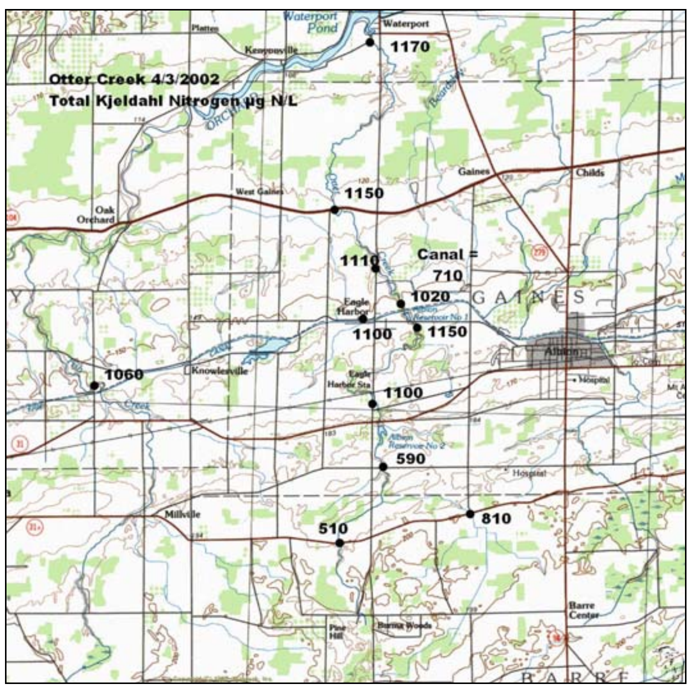
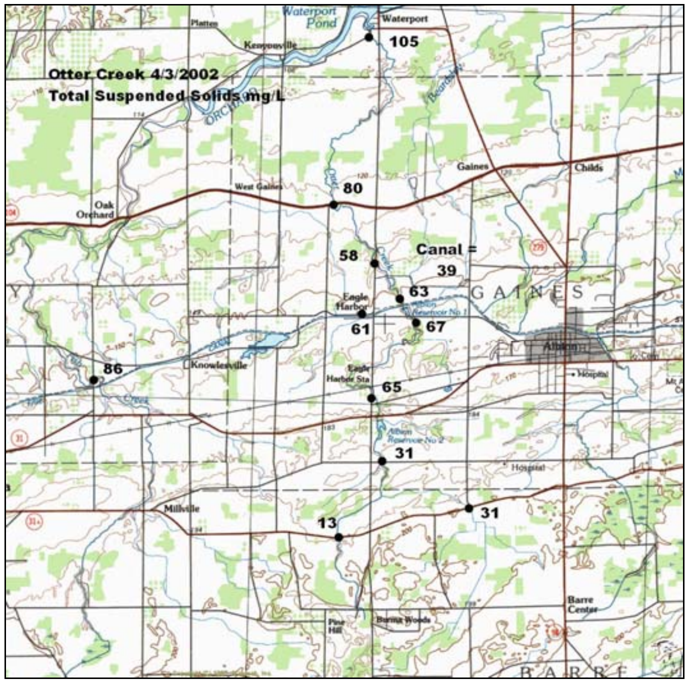


Figure 3. Nitrate and total Kjeldahl nitrogen for Otter Creek and the base of Fish Creek on 3 April 2002.



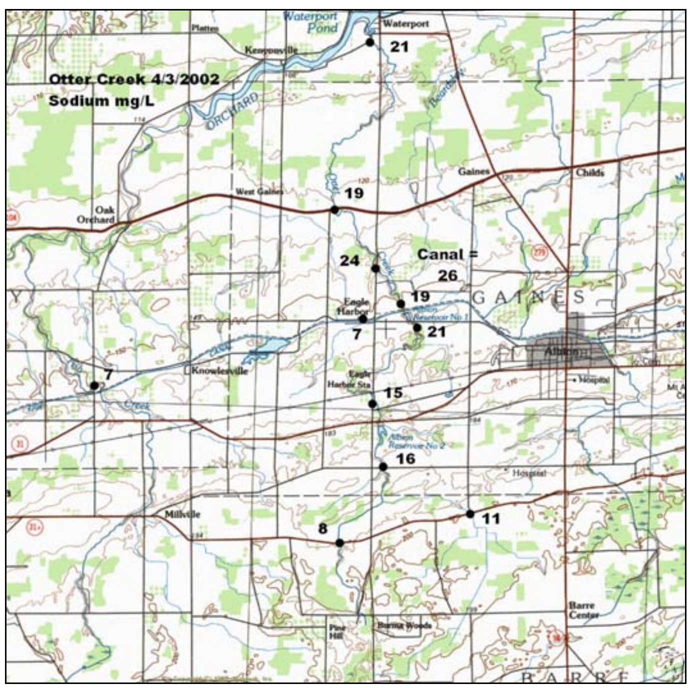
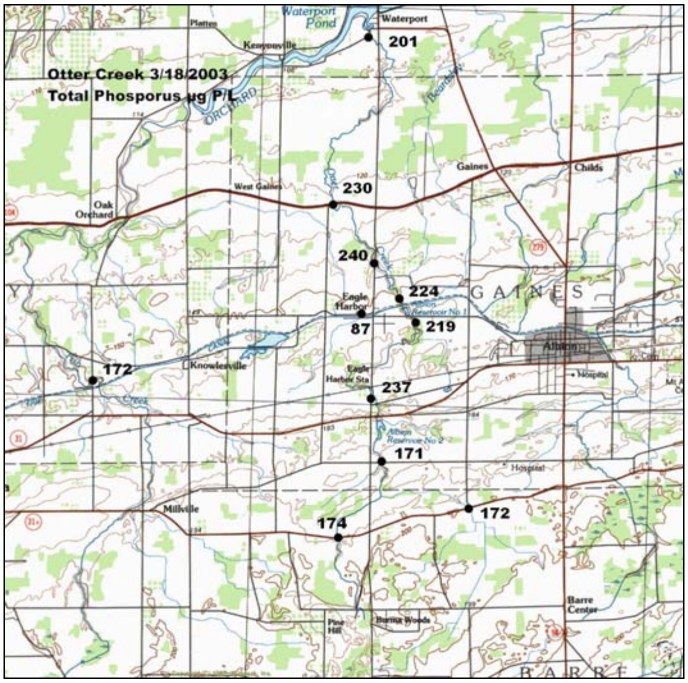


Figure 4. Total suspended solids and sodium for Otter Creek and the base of Fish Creek on 3 April 2002.



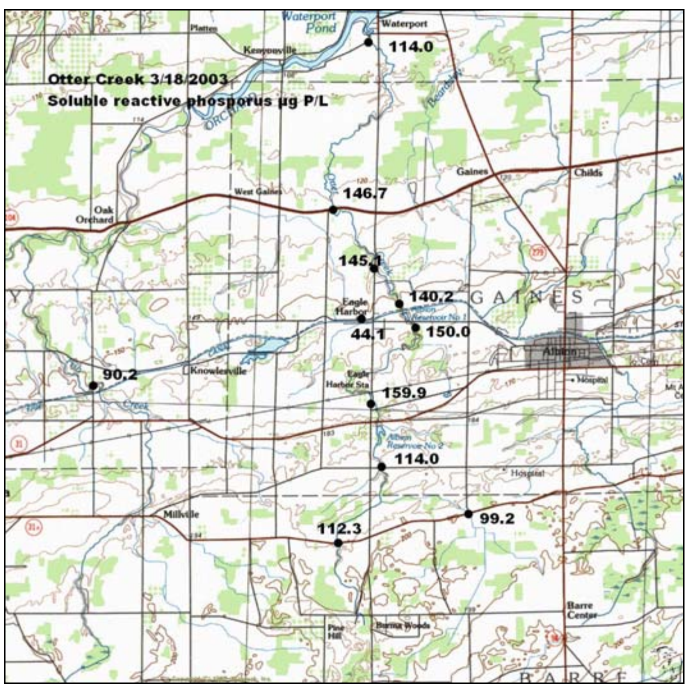
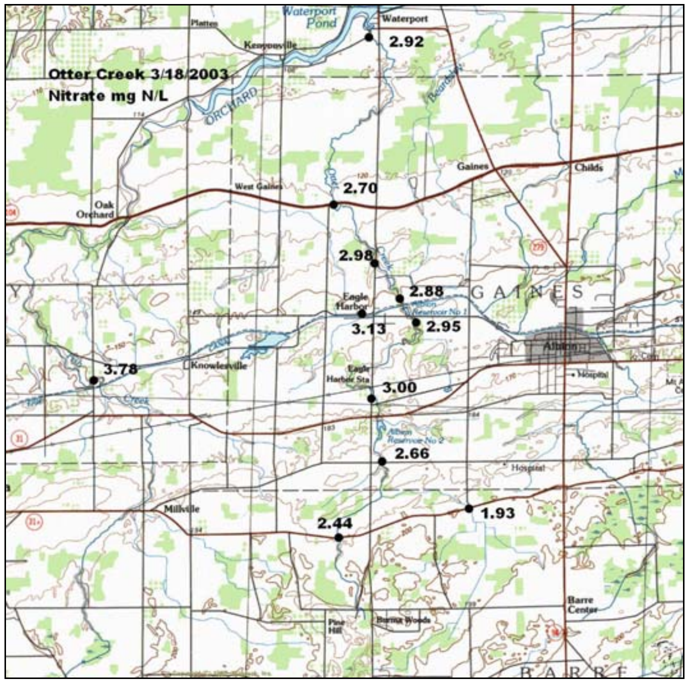


Figure 5. Total phosphorus and soluble reactive phosphorus for Otter Creek and the base of Fish Creek on 18 March 2003.



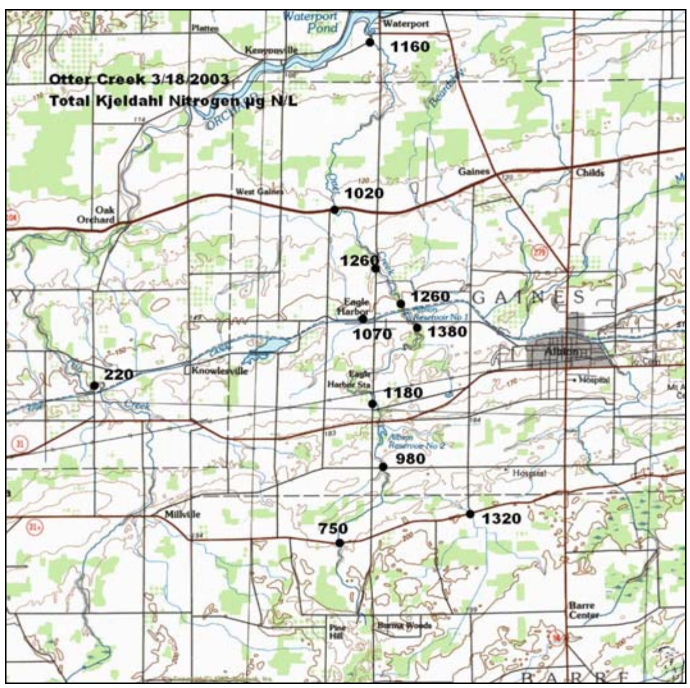
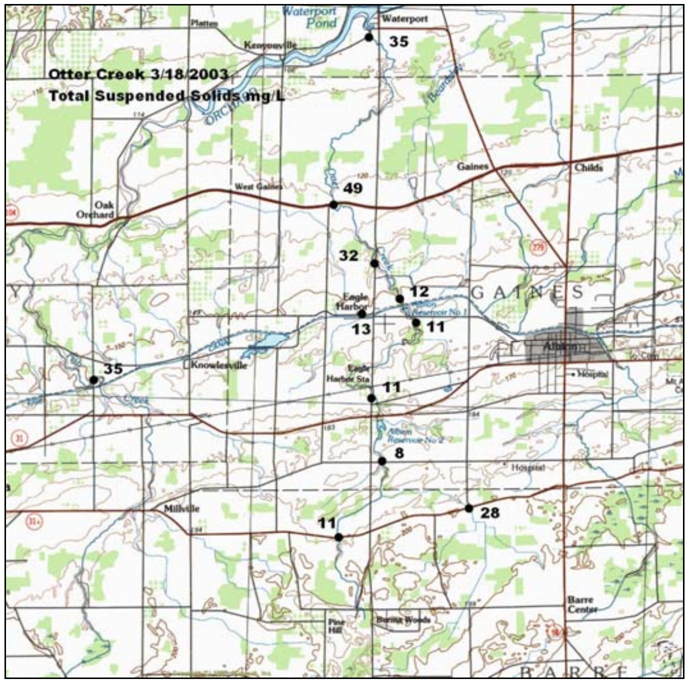


Figure 6. Nitrate and total Kjeldahl nitrogen for Otter Creek and the base of Fish Creek on 18 March 2003.



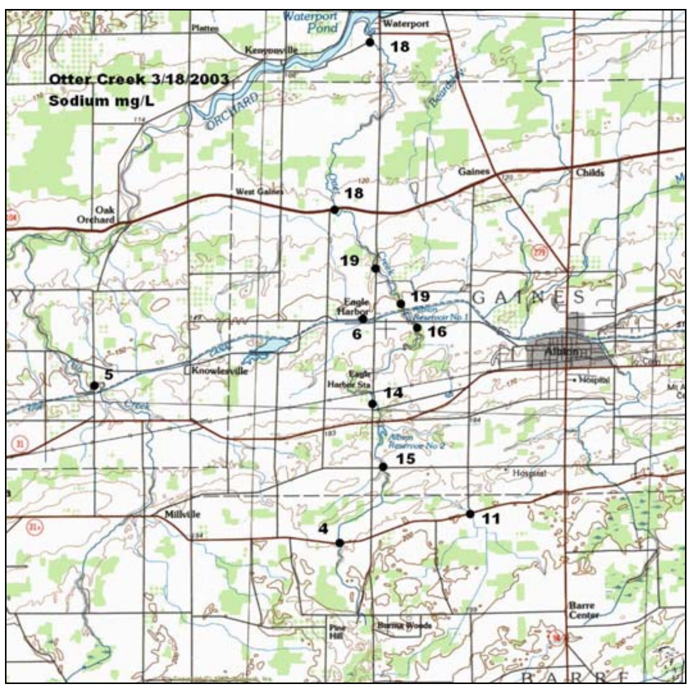
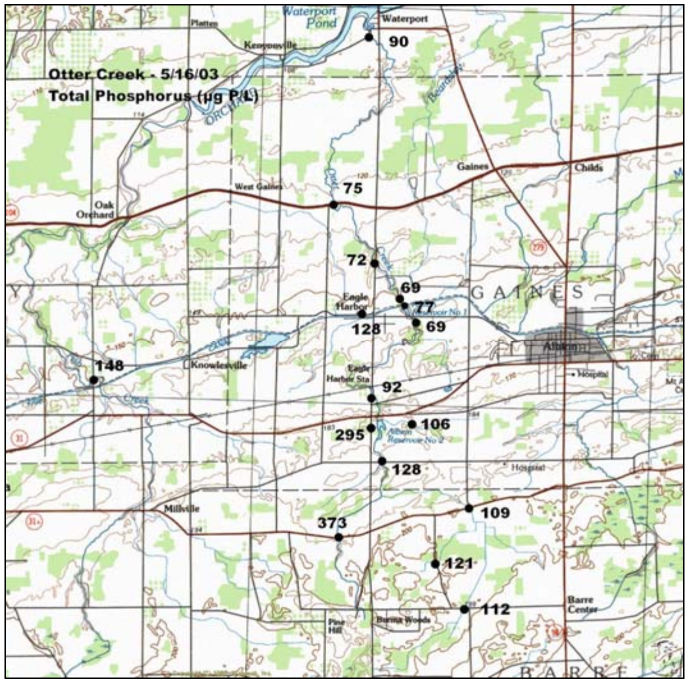


Figure 7. Total suspended solids and sodium for Otter Creek and the base of Fish Creek on 18 March 2003.



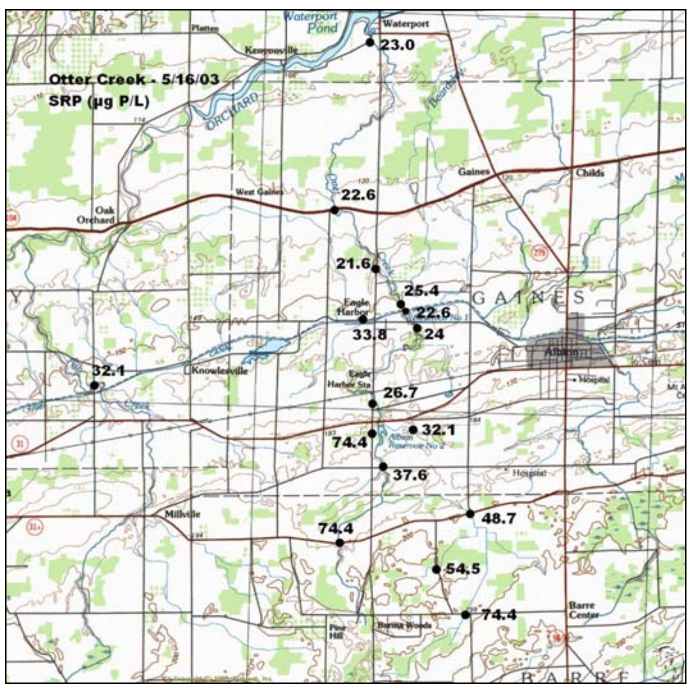
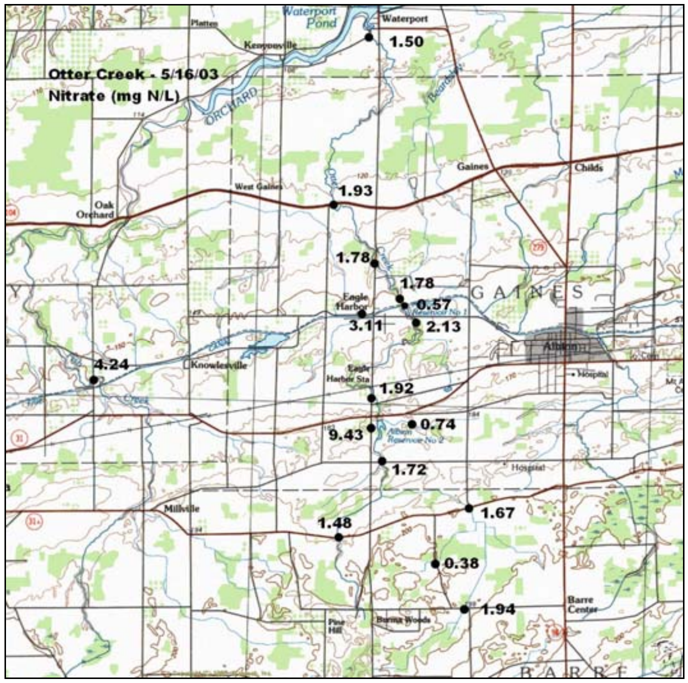


Figure 8. Total phosphorus and soluble reactive phosphorus for Otter Creek and the base of Fish Creek on 16 May 2003.



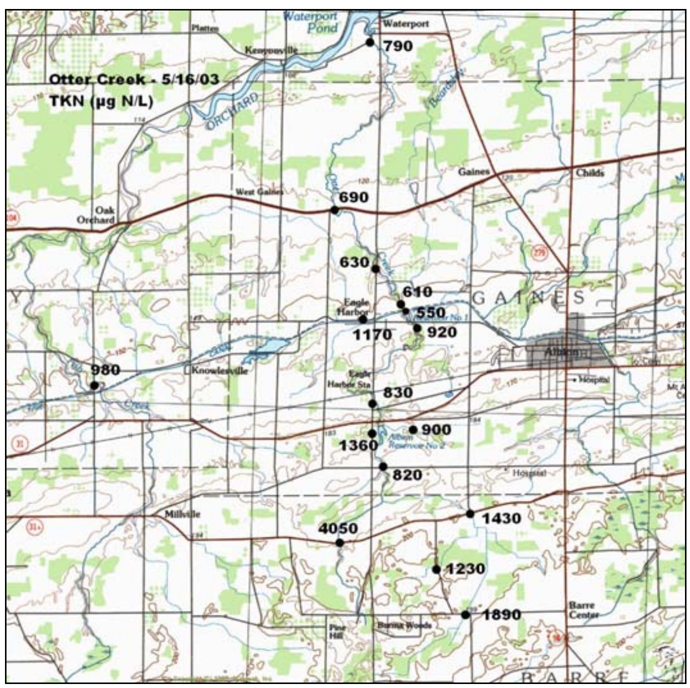
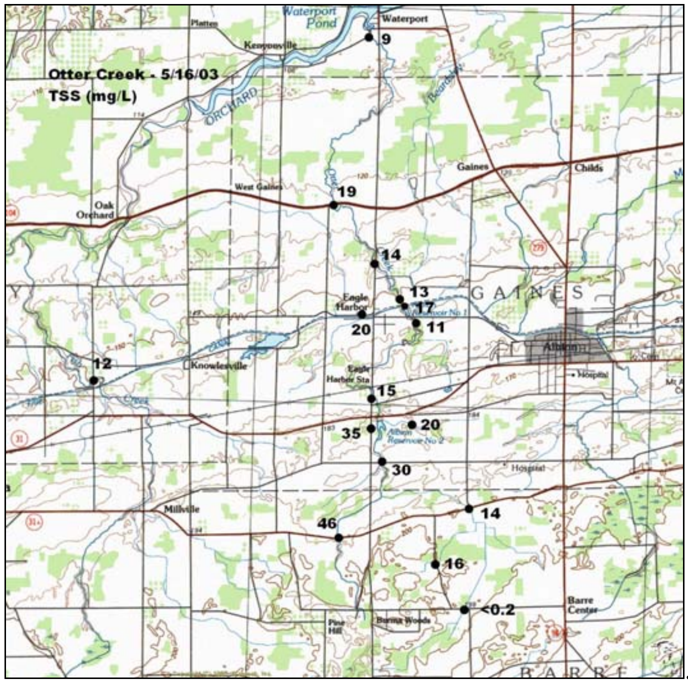


Figure 9. Nitrate and total Kjeldahl nitrogen for Otter Creek and the base of Fish Creek on 16 May 2003.



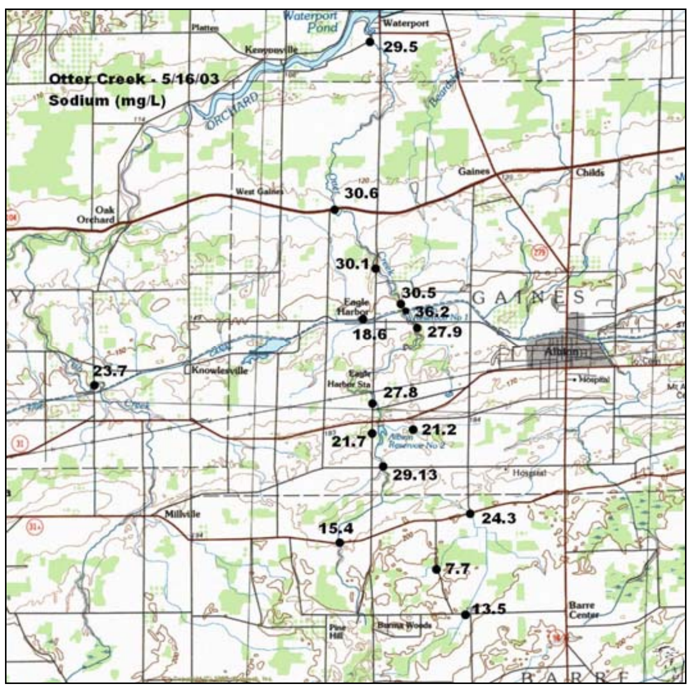
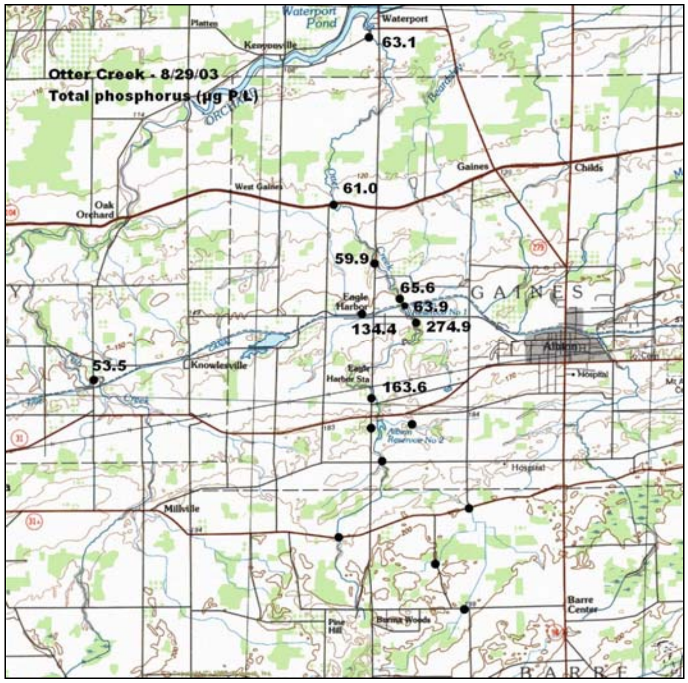


Figure 10. Total suspended solids and sodium for Otter Creek and the base of Fish Creek on16 May 2003.



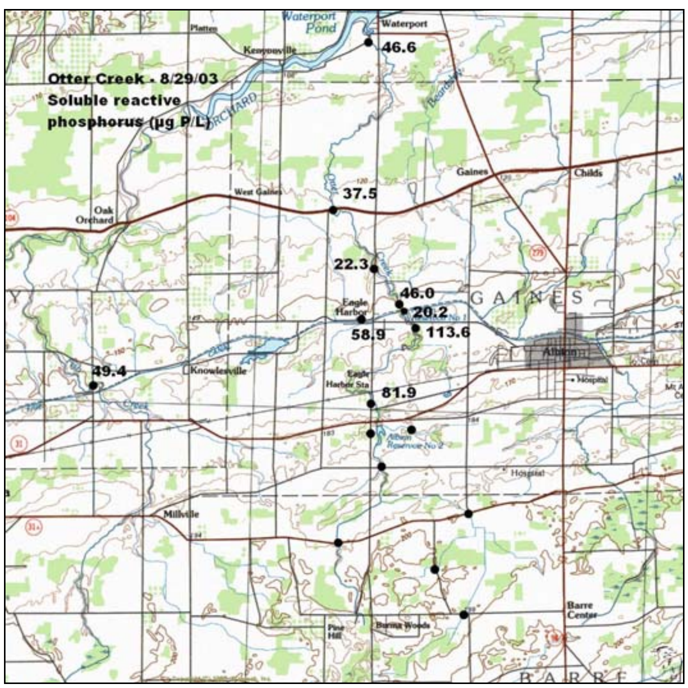
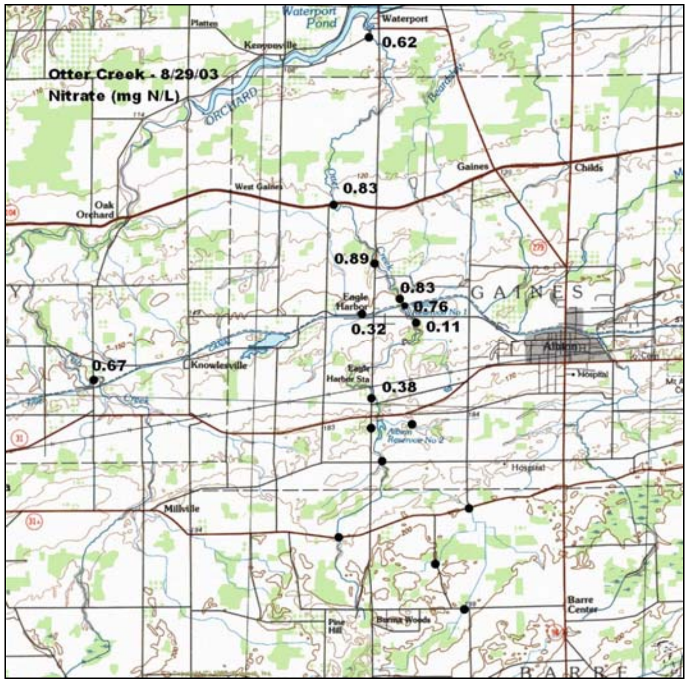


Figure 11 . Total phosphorus and soluble reactive phosphorus for Otter Creek and the base of Fish Creek on 29 August 2003.



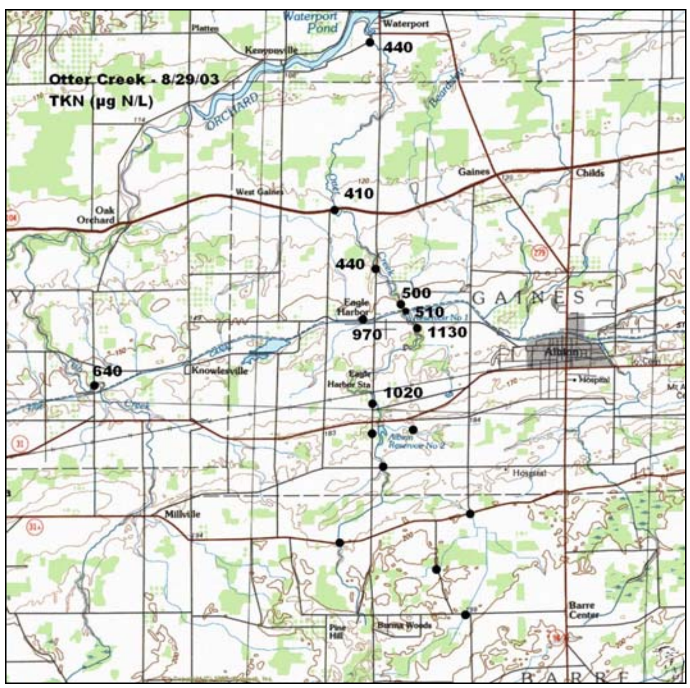
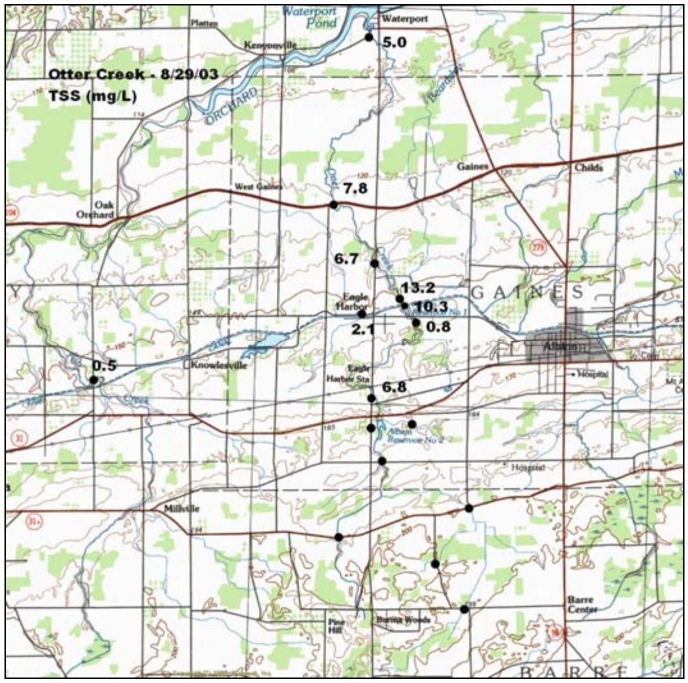


Figure 12. Nitrate and total Kjeldahl nitrogen for Otter Creek and the base of Fish Creek on 29 August 2003.



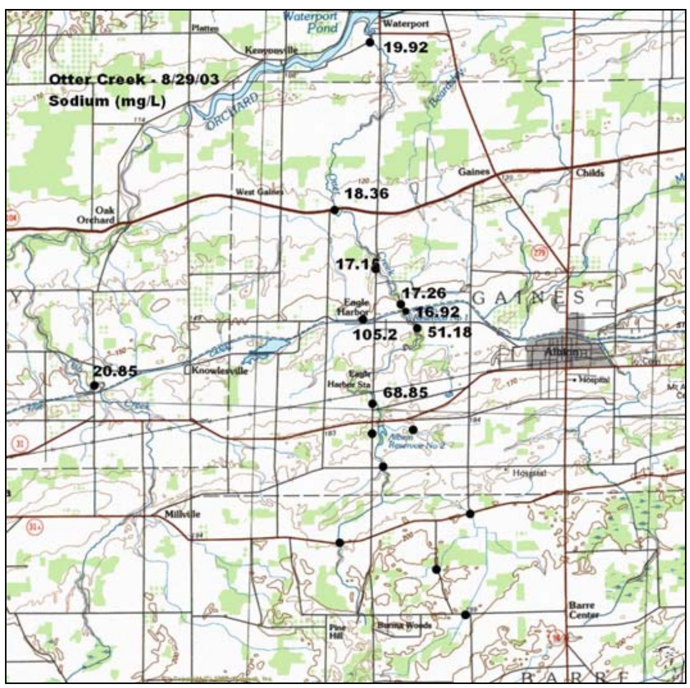


Figure 13 . Total suspended solids and sodium for Otter Creek and the base of Fish Creek on 29 August 2003.

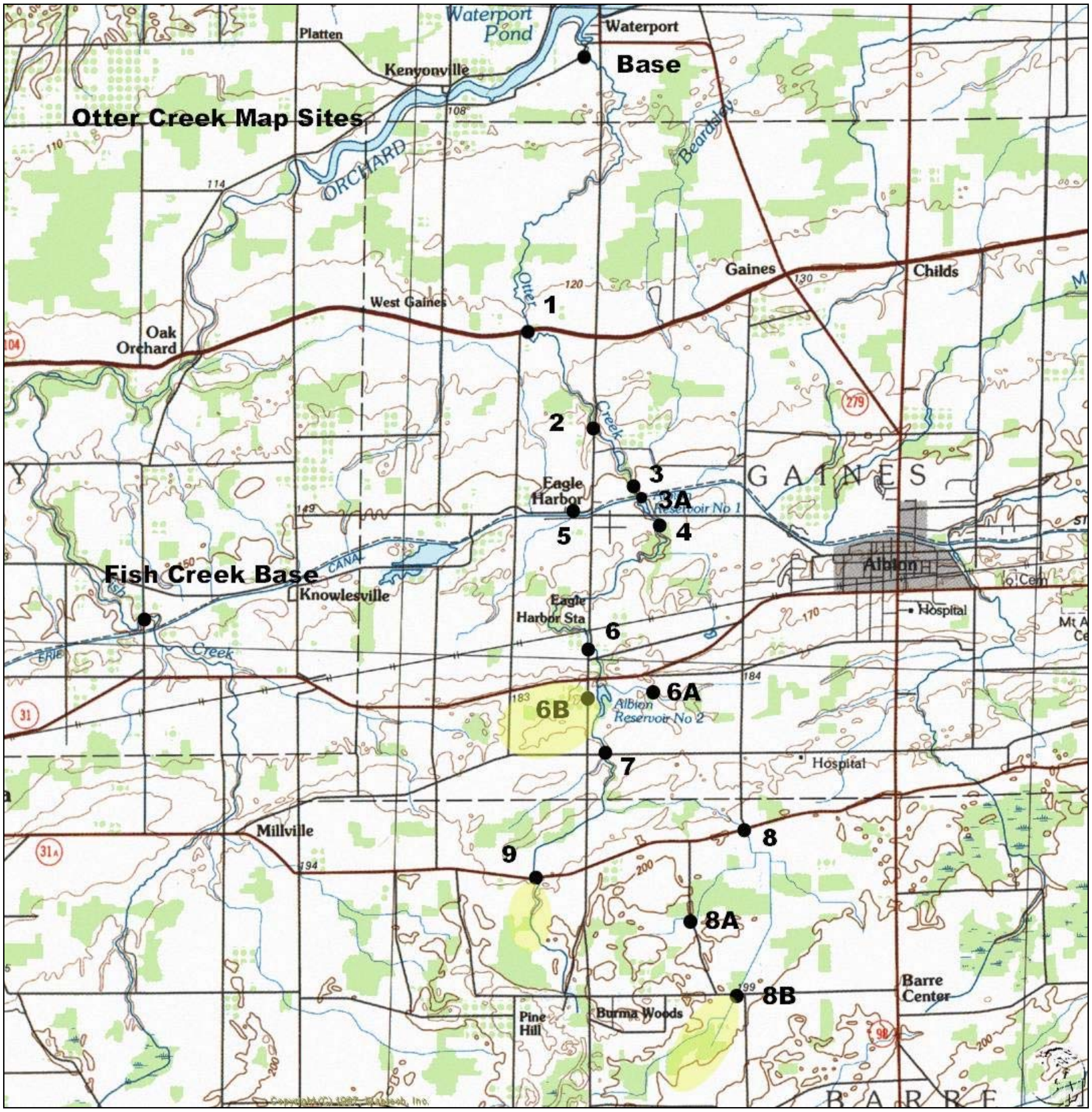


Figure 14. The Otter Creek watershed with areas that contained sources (in yellow) of nutrients and soil highlighted.